Single amplifier circuits, such as a common emitter, common base, and common collector amplifiers are seldom found alone, as a single stage amplifier, in a system. Most systems have two or more amplifiers connected together (coupled) in various ways. In this case, each amplifier circuit is called a stage because the AC signal in the system goes through "stages" or steps of amplification. Refer to figure 1.

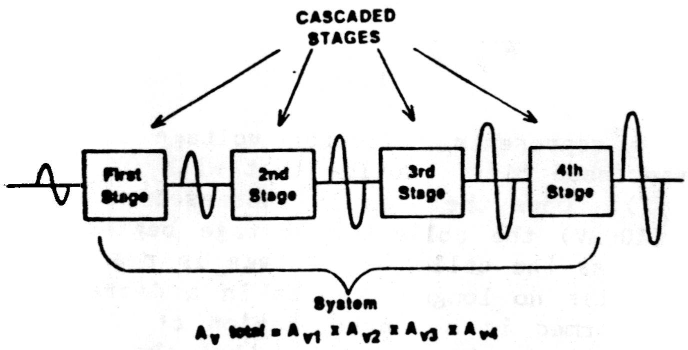


figure 1

If the output of one amplifier is connected (coupled) to the input of another amplifier the stages are said to be connected in "cascade". The benefit of cascaded amplifiers is to develop an Eout larger than either stage alone can develop. In fact, the overall gain of the cascaded amplifiers (called system gain) is the product of each individual stage gain, or AV total (total voltage gain) = AV1 (gain of the first stage) X AV2 (gain of the second stage) X AVn (gain of any number of stages). Because of this the gain of a single stage is not as important as the system gain. Designers usually set individual stage gains relatively low to reduce signal distortion. Signal distortion is a term used to describe the condition where the output signal of an amplifier is not a true representation of the input signal. Signal distortion is a result of the transistor not operating in the linear portion of it's output curve. Refer to figure 2. The graph is developed to show the relationship between collector voltage and emitter/base bias.

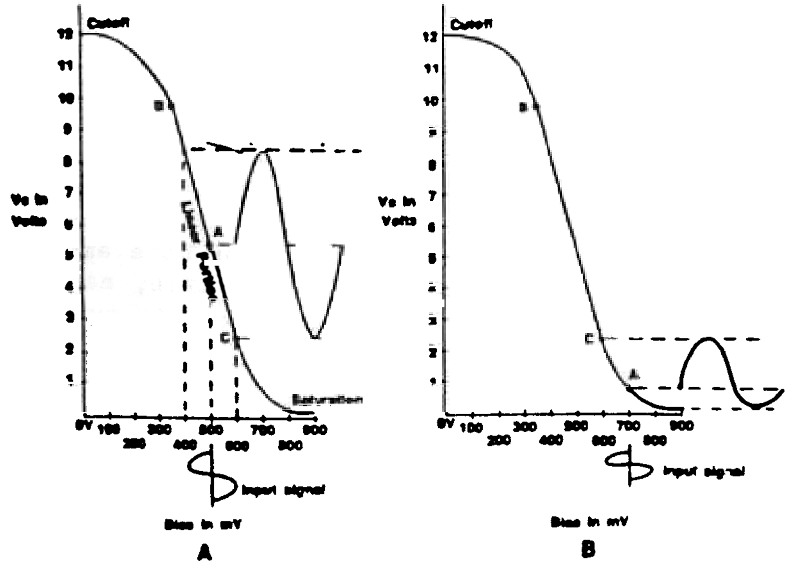


figure 2

The vertical axis represents collector voltage and the horizontal axis represents emitter/base bias. Notice that with 0V of bias the collector reads 12V (cutoff). Once the bias is increased enough to make the transistor conduct (100mV) the collector voltage begins to drop. At around 800mV of forward bias the collector voltage is reading 120mV and any further increase in bias no longer results in a decrease in collector voltage. The curve formed is a representation of the relationship between bias and transistor conduction. Observe that the line between cutoff and saturation is not straight. A portion of it is straight between points B and C. This would be called the "linear" portion of the curve. If the transistor is biased so that the operating point, point A, never moves off the linear portion of the curve any signal applied will be reproduced without any distortion. Notice that in figure 2A the input signal causes the bias to vary between 400 and 600 mV. This results in the operating point varying between 2.5V and 8.5V. The resultant signal is a good reproduction of the input. In figure 2B the transistor is biased at 700mV and the same amplitude signal causes the bias to vary between .6V and .8V Notice that the operating point, point A, dropped below point C when the bias was 800mV. This resulted in the output signal no longer being a good reproduction of the input signal. Observe that the positive alternation is now larger than the negative alternation. This is distortion. The output signal is no longer a good reproduction of the input signal. It's because of this that you would use more stages, operating with less individual gain, than attempt to use fewer stages with greater gain.

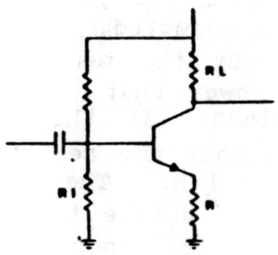
TRANSFORMER COUPLING

Recall from the lesson on transistor configurations that the various configurations have different input and output impedances. Figure 3 is a chart showing the comparison of input and output impedances of the three basic configurations.

	CB	CE	CC
Input Z	30Ω / 150Ω	300Ω / 500Ω	500KΩ
Output Z	300KΩ - 1MΩ	30KΩ / 50KΩ	100KΩ

figure 3.

The input impedance of a transistor amplifier stage is the total opposition "seen" by the generator when looking into the transistor. See figure 4A. A close approximation of input impedance equals R1 in parallel with Re. The resistance seen determines the signal current that will flow in the input circuit. The output impedance of the transistor amplifier stage is the resistance or opposition the load "sees" when looking back into the amplifier. This is the internal resistance of the amplifier. See figure 4B. A close approximation of output impedance is the output impedance equals the load resistor.



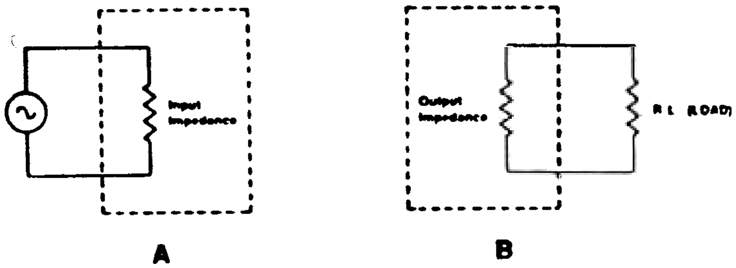


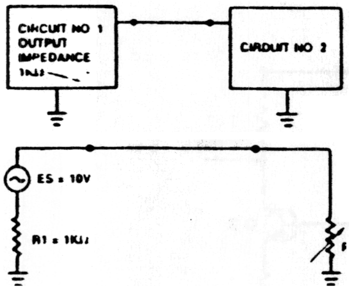
figure 4

It must be remembered that impedance is the total opposition to current flow. The two resistors shown represent the equivalent resistance of all the amplifier's circuit DC components in addition to any reactive components (capacitors/inductors). The generator in 4A could be another amplifier. The resistor (RL) in 4B could also be another amplifier. Compare the input and output impedance of the common emitter amplifier in figure 3. If two common emitter amplifiers were coupled together the high output impedance of the first amplifier would be connected to the low input impedance of the second amplifier. For instance, if a 50K ohm output impedance was connected to a 500 ohm input impedance, this would be called an impedance mismatch and would result in a severe loss of amplifier gain. If the output impedance of an amplifier was 50K ohms it would develop a signal that was proportional to that output impedance. If another amplifier is now connected to it and the second amplifier's input impedance is 500 ohms and these two impedances are in parallel, the total impedance will be something just under 500 ohms. This signal is developed across a much smaller impedance and will be much smaller. This is referred to as the second stage loading down the first stage.

If the purpose of coupling the two amplifiers together was to transfer maximum power between the two stages it would be important that the input and output impedances between the two stages be matched.

We will now discuss what is meant by the term maximum power transfer. Refer to figure 5. Circuit No. 1 is respresentative of a power source. It could be a power supply or an amplifier stage. Circuit No. 2 is a load that is being driven by the source (ckt. No. 1). It could be a variable resistor as shown or possibly another amplifier stage. For this discussion assume the source will supply a constant 10v and its internal resistance (output impedance) is a constant 1K Ω . R_2 represents the input impedance of the next stage and will be made variable to aid in the discussion.

If a device capable of measuring the power ($P = I_2R$) is attached to the load (R_2), when the load is adjusted, the power developed by the load will vary and be indicated by the measuring device. R_2 can then be adjusted until the maximum power that is capable of being developed by R_2 and the source is obtained. If the resistance of R_2 is read at this time, it would be seen that the resistance (impedance) of the load (R_2) and the source (R_1) match. The chart in figure 5 has been developed to show this action. Notice that as R_2 is increased the power developed developed by R_2 (PR2) increased up to a certain point. Maximum power is developed at R_2 when R_1 and R_2 match (are the same value). As R_2 is increased further, the power begins to decrease. This is due to the continued decrease in circuit current (I) as a result of the increase in total circuit resistance. Notice also that as R_2 increases the voltage across it (ER2) increases. If the load resistance is much larger than the source resistance, most of the circuit voltage will be developed across the load. If this idean was applied to the amplifiers, there would be a large voltage developed across R_2 but very little power. Notice also, that the larger the load resistance, the lower the total power developed in the circuit.



R2	I = EAPP / RT I	ER2 = IR2 X R2 ER2	PR = I2R1 PR1	PR2 = I2R2 PR2
100Ω	9mA	900mV	81mW	8.1mW
200Ω	8.3mA	1.7V	68.9mW	1.4mW
500Ω	6.7mA	3.35V	44.9mW	22.4mW
1KΩ	5mA	5V	25mW	25mW
2KΩ	3.3mA	6.6V	11mW	21.8mW
5KΩ	1.7mA	8.5V	2.9mW	14.5mW
10KΩ	.91mA	9.1V	.83mW	8.3mW

figure 5

An example of the need to match impedances would be in the final power amplifier stage of a radio receiver. In this case the received signal has been amplified to sufficient strength to drive the power amplifier. It is desirable to transfer maximum power from the power amplifier to the speaker. It would then be necessary to match the impedances between the two stages.

It should be noted that maximum power transfer is not always required. In cases where signal or voltage gain is of primary importance it is not necessary to match impedances between stages.

Transformers are ideally suited to match the impedance of the output of one amplifier to that of another amplifier. Impedances can be matched by using a transformer with the proper turns ratio.
The equation in figure 6 can be used to determine this ratio.

$$N = \frac{Zp}{Zs}$$

where: N = turns ratio of the transformer

Zp = impedance of the primary.

Zs = impedance of the secondary

figure 6

An example of the calculation of the turns ratio is as follows: Refer to figure 7.

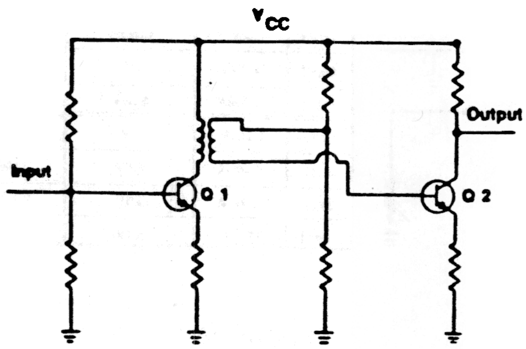


figure 7

Assume that the output impedance of Q1 is 30 K ohms, while the input impedance of Q2 is 1K ohm. If the amplifier is transformer coupled, what turns ratio would be used?

solution: $$N = \frac{Zp}{Zs}$$

$$N = \frac{30{,}000}{1000}$$

N = 30:1

In order to match the impedances of the first and second stages, the transformer should have a 30:1 turns ratio. Generally, the transformers used for coupling are step-down transformers. Because of this action, transistor Q1 sees a load impedance of 30K ohm instead of 1K ohm.

Another important characteristic of transformer-coupled amplifiers is that the output stage is isolated from the next stage. Therefore, the DC operating voltages found in the amplifier of Q1 will not show up in the next stage. This means that a shift in the operating point of Q1 will not affect the operating point of Q2.

The actual coupling of one stage to another is done by normal transformer action. Refer to figure 6. An ac signal applied to Q1's base produces a change in base current, resulting in a change in collector current. The changing collector current will also flow in the primary winding of transformer T1. As the current in T1's primary varies, the magnetic field developed by the signal current also varies and induces currents into the secondary that are representative of the input signal. The varying current in T1's secondary will develop a signal which is applied to the base of Q2 which will cause Q2 to vary it's conduction level. Therefore, we see that the output of Q1 has been coupled to Q2.

The primary advantage of transformer coupling is its ability to impedance match. It also serves to isolate the DC voltages of individual stages.

The primary disadvantage of transformer coupling is the poor frequency response of transformers. The impedance of the transformer windings varies with frequency. For example, if the transformer's primary has an inductance of 5 henrys, at 60 Hz the inductive reactance would be:

$$XL = 2 \quad fL$$

$$XL = 6.28 \times 60 \times 5 = 1{,}884 \text{ ohms}$$

At 1000 Hz the inductive reactance would be

$$XL = 2 \quad fL$$

$$XL = 6.28 \times 1000 \times 5 = 31{,}400 \text{ ohms}$$

At 100,000 HZ the inductive reactance would be

$$XL = 2 \quad fL$$

$$XL = 6.28 \times 100{,}000 \times 5 = 3.14 \text{ Mohms}$$

From these figures it should be obvious that transformers are frequency sensitive devices. If a transformer is wound to couple a particular frequency, frequencies above and below the selected frequency will not be effectively coupled. Transformers will pass a very narrow band of frequencies. A second disadvantage of transformer coupling is they are comparatively large, take up considerable space, and can add weight to the circuit. A third drawback is cost. When transformers are designed to provide a wide-frequency range with small size the cost is frequently too high.

RC-COUPLING

The most commonly used type of coupling is called RC-Coupling. RC Coupling has the advantages of wide frequency response and relatively small cost and size. The main disadvantage is it's inability to provide impedance matching. Because impedance matching must be compromised for better frequency response, the gains of individual RC-Coupled stages are somewhat reduced and often an extra stage must be added to produce system gains needed.

An RC-Coupling network is shown in figure 7. The network of R2 and C1 enclosed in the dashed lines is the coupling network. The circuitry for Q1 and Q2 has been left incomplete so you can concentrate on the coupling network.

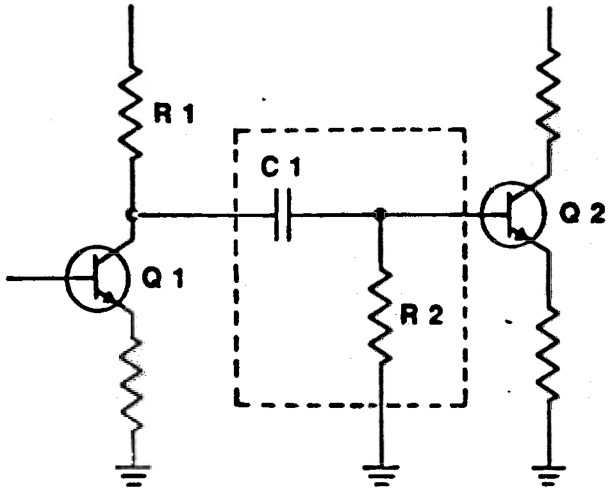


figure 8.

C1 is the coupling capacitor which connects the output of Q1 to the input of Q2. R2 will develop the signal to be applied to the base of Q2. C1 acts as a limiting factor at low frequencies because its reactance increases with a decrease in frequency and some point will be reached when a voltage drop will appear across it. This will reduce the size of the signal being applied to Q2. Because of the effect decreasing the frequency has on C1, RC-Coupling is normally used only in medium and high frequency applications. At these frequencies, the reactance of C1 is so small that it can be considered a short to the signal. C1 will also isolate any DC voltage developed at the collector of Q1 from the DC bias developed at the base of Q2. The capacitive reactance, (XC), of C1 must be low for the signal frequency being coupled, and the resistance of R1 must be high with respect to this XC, (at least 10 times as great), so that as little signal voltage as possible will be lost across the coupling network. For an explanation of circuit operation refer to figure 9.

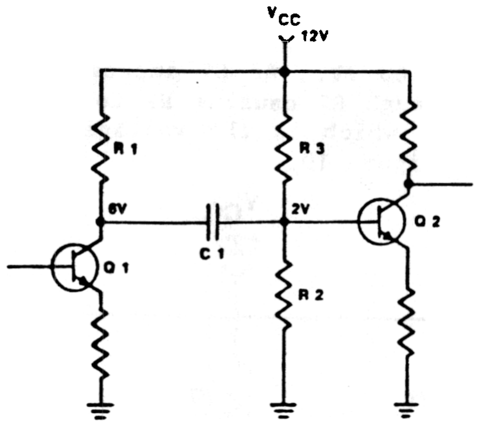


figure 9

Assume that Q1 and Q2 are in a static state, (no signal applied). Current flow through Q1 develops 6VDC at the collector (Vc). Current flow through the base biasing network of Q2 (R2 and R3) develops 2VDC at the base of Q2 (Vb). C1 charges through R2 to the difference in the potentials on either side of it and will assume a charge of 4VDC (6v-2V = 4V). When a signal is applied to the base of Q1, the current changes through the collector resistor (R1) will cause the Q1 collector voltage to vary. In this instance assume the collector rises to 7V. See figure 10.

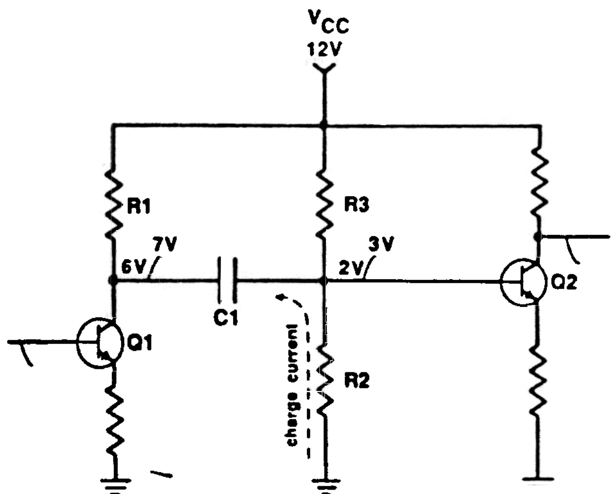


figure 10

As collector voltage rises, the tendency of C1 is to charge to the higher potential. However, a capacitor cannot change its charge instantly. Recall that it takes 5 time constants for a capacitor to charge. As C1 starts to change its charge, charge current will be felt through R2. C1 will now start to charge to 7V. As C1 increases its charge, additional current will be drawn through R2 causing R2 to increase its voltage drop. The voltage at Q2's base, which is the voltage drop across R2, will now rise from 2V to 3V. See figure 10.

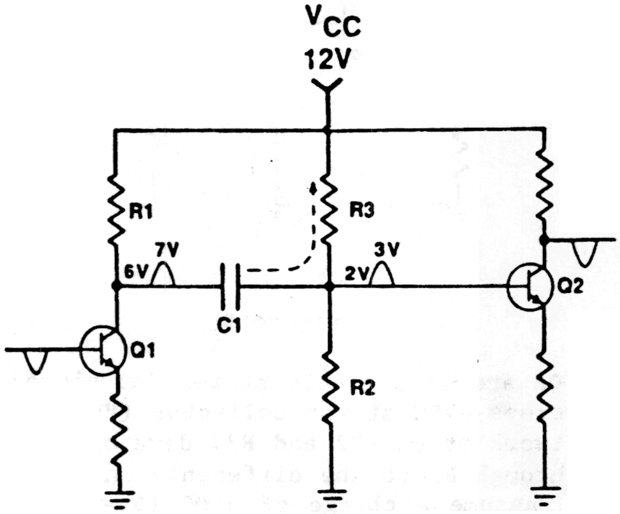


figure 11

Refer to figure 11. As the collector voltage at Q1 starts to decrease, C1 will attempt to discharge. Electrons being forced off the right plate of C1, as it attempts to discharge, will now flow through R3 increasing its voltage drop which results in a decrease in the voltage drop across R2.

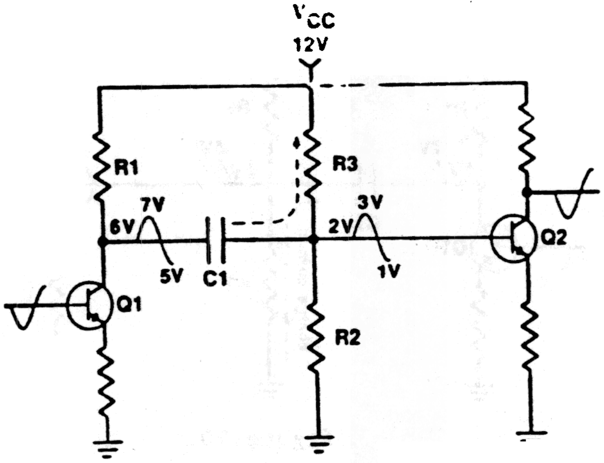


figure 12

Refer to Figure 12. As Q1's collector voltage decreases further it will result in C1 decreasing its charge further. As Q1 collector voltage drops to 5V, C1 will continue to attempt to discharge. As C1 continues to discharge the voltage drop of R2 decreases to 1V.

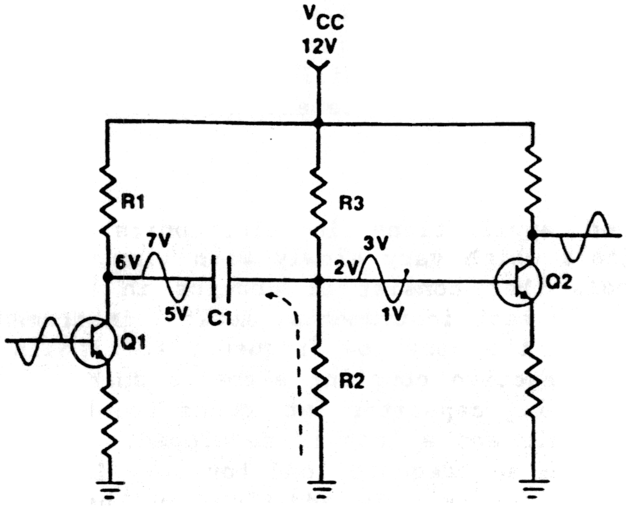


figure 13

Refer to figure 13. As Q1 collector voltage starts to go positive, C1 will start to increase it's charge. This causes the current through R2 to increase which results in the voltage drop across R2 increasing. When the collector voltage of Q1 returns to its original 6V the voltage at Q2's base will have returned to 2V.

Notice that the signal developed at the collector of Q1 has caused C1 to vary its charge resulting in varying current level through R2 and R3. The signal developed by these currents resulted in a signal being developed at the base of Q2 which is identical to Q1's collector signal. Although the signal on both sides of the capacitor are identical, the base signal of Q2 did not pass through C1, it just appears to. However, when referring to signal flow, we speak of it as if it did. Normally we would say "the signal developed by Q1 will be coupled by C1 to Q2's base".

In order for C1 and R2 to be considered a coupling circuit the "time constant" of these two components, C1 and R2 must be at least 10 times as long as the period of the signal they will be required to couple. As a result, the capacitor never completely discharges. This is because the time constant of the coupling circuit is long in respect to the signal being coupled. C1 will start to discharge but since the discharge time is a long time constant in respect to the signal, the signal causes it to recharge before it can discharge completely.

As mentioned earlier, the capacitive reactance is low to the input signal. If the capacitive reactance of C1 is low to the input signal, then most of the signal will be developed across R2. If the input frequency is decreased, the capacitive reactance of C1 will increase. This results in some of the input signal being dropped by C1. If the frequency is decreased further, more signal is dropped across C1 and less is developed by R2 which is the input to the next stage. If the input frequency drops enough, eventually, the circuit will cease to operate as a coupling circuit because the capacitive reactance is so great no signal will be developed by R2. It is the capacitive reactance that determines the minimum frequency the coupling circuit will pass. The higher the input frequency the lower the capacitive reactance and the better the circuit functions.

DIRECT COUPLING

Many specialized applications in electronics require amplifiers that respond to signals which vary slowly with time, (very low frequency signals), or signals that consist of changes in DC level. Some of these applications are in test instruments, medical instruments, and analog computers. Because of the very low frequency ac signals involved the amplifiers cannot use reactive coupling elements such as capacitors or transformers. The coupling capacitor introduces too high a reactance for very low frequency signals and a loss is developed. The coupling transformer, in order to provide an adequate load for very low frequency signals, can be very large and costly. In addition, neither the capacitor nor the transformer is capable of coupling DC changes when such signals are to be amplified.

The solution to the problem is the use of a direct coupled circuit. An amplifier of this type will respond to extremely low frequencies down to and including DC and will produce no phase shift of the signal because there are no reactive components. Refer to figure 14.
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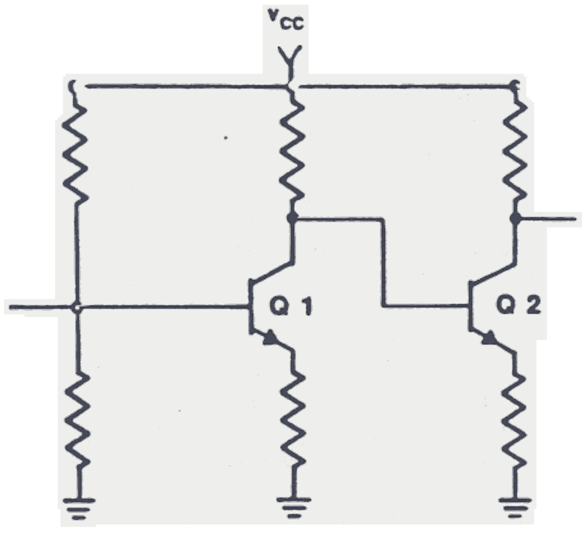


figure 14.

The output of Q1 is taken from the collector and fed directly to the base of Q2. The collector voltage of Q1 is, therefore, also the base voltage of Q2. In most circuits this would be an excessive base voltage which would cause an excessive value of base current and burn out Q2. The excessive voltage at the base of Q2 can be compensated for by increasing the value of Q2's emitter resistor. A large value of Re produces a large voltage drop which cancels a portion of the voltage applied to the base. The disadvantage of this approach is that Re usually has to be high in value; thus a large signal voltage will be developed across it resulting in degeneration. The degeneration will greatly reduce the gain of Q2. Introduction of a bypass capacitor across Re introduces a reactive component that will not filter well enough at very low frequencies.

The stability of a DC amplifier presents a greater problem than that of the RC-Coupled type. As the temperature rises in a DC amplifier the operating point of Q1 will shift. This causes a change in the collector voltage of Q1, which causes a change in the base bias of Q2 and shifts the operating point of Q2. The temperature change which affects Q1 also affects Q2, further shifting the operating point of Q2. It can be seen that the stability problem is more severe in DC amplifiers as each stage amplifies the drift. Any small movement of the static Q point in the first stage will be amplified by each successive stage until there is a very large change at the final stage output. In RC-coupled or transformer coupled amplifiers, the drift in one stage is not coupled to the next stage. A very common configuration of a direct coupled amplifier is named a DARLINGTON PAIR. See figure 15.

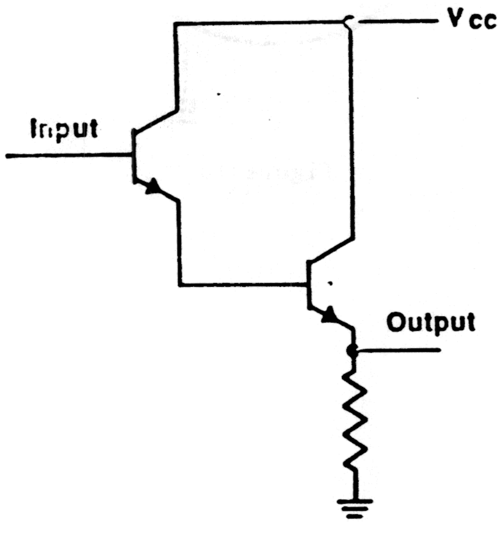


figure 15

The advantages of this direct coupled amplifier is simple circuitry, a minimum number of components, a higher input impedance and an overall current gain that is equal to slightly more than the current gain of Q1 times Q2. The circuit is also excellent for small signal inputs since the collector current of Q1 is small and Q1 will develop very little noise due to less base recombination taking place.

The Darling Pair is often used as an impedance matching device to match a high output impedance of one circuit to a low input impedance of another circuit.

The use of the Darlington Pair is so frequent that manufacturers produce the circuit fabricated in a single package with three leads to be used as a single high gain transistor. See figure 16.

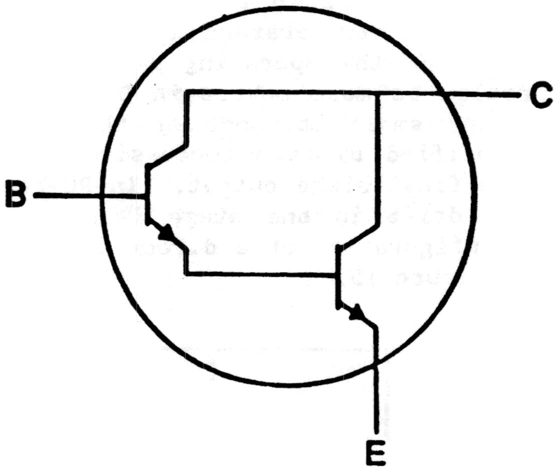


figure 16

BANDWIDTH

Bandwidth is a term used to describe the various frequencies a particular amplifier will effectively amplify. Figure 17 is a Frequency Response curve of an audio amplifier. An audio amplifier is an amplifier that is designed to amplify frequencies in the audio range, (15Hz to 20KHz). The curve is a picture of the performance of an amplifier with different frequencies applied to it.

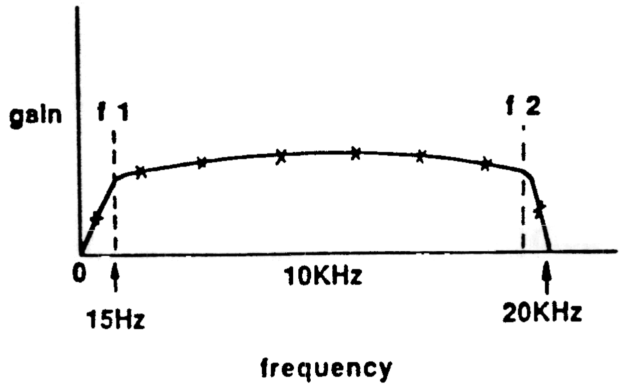


figure 17

The amplifier for which the frequency response curve is created is tested at various frequencies. At different frequencies the input is set to a predetermined signal level. The output is then measured and marked on the graph. The graph is marked "frequency" along the horizontal axis and "gain" along the vertical axis. When the points have been plotted for all the frequencies tested, the points are connected to form the response curve. Some amplifiers should be flat across a band of frequencies. This means that the amplifier will amplify all frequencies within a certain range the same amount. Other amplifiers are designed to amplify a very narrow band of frequencies. Their response curve would resemble the one in figure 18.

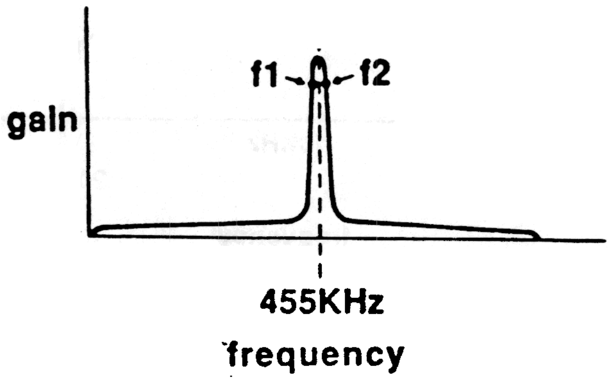


figure 18

Since an audio amplifier is required to amplify all frequencies in the audio range its curve will resemble the response curve in figure 17.

Notice in figure 17 that the lower frequency limit is labeled f1 and the upper frequency is labeled f2. The f1 and f2 points are also known as half power points. The half power points are the points at which the signal amplitude has dropped to .707 percent of the maximum signal amplitude. Any frequency below the f1 or above the f2 point is not considered a usable output from the amplifier. The bandwidth of the amplifier is the difference between the f1 and f2 points. For instance if the f1 point was 20Hz and the f2 point was 150KHz the bandwidth of the amplifier would be (150KHz-20HZ = 149980Hz). The upper and lower limits of the amplifier are determined by the reactive components, (capacitance and inductance) in the amplifier. The reactive components are sensitive to changes in frequency. A decrease in frequency results in XL decreasing and XC increasing. An increase in frequency results in an increase in XL and a decrease in XC. Most amplifiers are RC-Coupled. The reactance of the coupling capacitors and by-pass capacitors will have a great influence on the bandwidth of the amplifier. In addition to the coupling and by-pass capacitors there is also a certain amount of capacitance and inductance in the

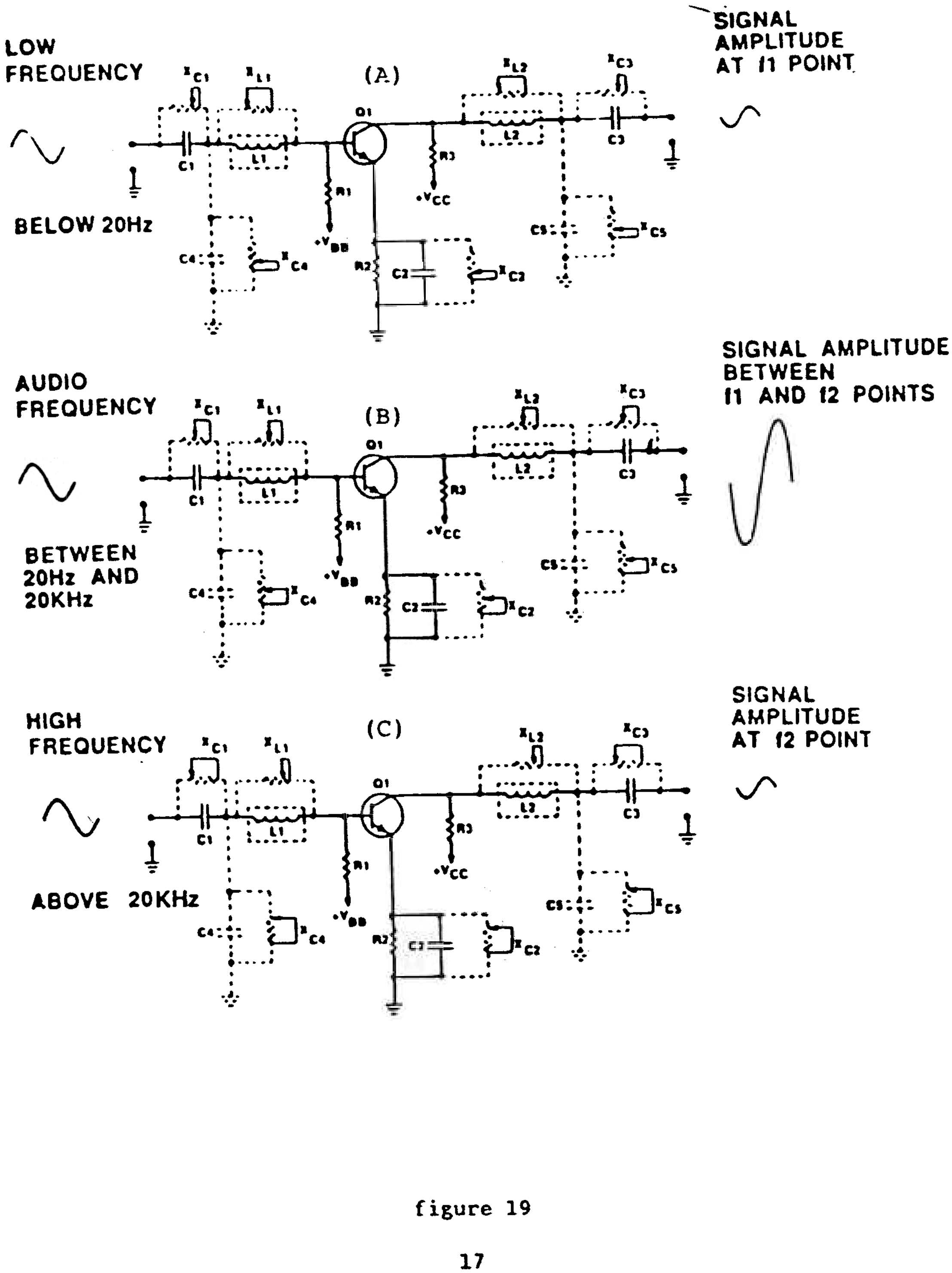

LOW
FREQUENCY
(A)
BELOW 20Hz
SIGNAL
AMPLITUDE
AT f1 POINT
AUDIO
FREQUENCY
(B)
BETWEEN
20Hz AND
20KHz
SIGNAL AMPLITUDE
BETWEEN
f1 AND f2 POINTS
HIGH
FREQUENCY
(C)
ABOVE 20KHz
SIGNAL
AMPLITUDE
AT f2 POINT

figure 19

circuit wiring. To illustrate this point figure 19 shows audio amplifier circuits with the capacitance and inductance of the wiring represented as "phantom" capacitors and inductors. The reactances of the capacitors (XC) and the inductors (XL) are shown as "phantom" variable resistors. View (A) shows the circuit with a very low frequency, (less than 20 Hz), input signal, view (B) shows the circuit with an audio frequency input signal, and view (C) shows the circuit with a high frequency, (above the audio range), input signal.

The actual circuit components are C1, C2, C3, R1, R2, R3, And Q1. C1 is used to couple the input signal. R1 develops the input signal. R2 is used for proper biasing and temperature stability. C2 is a by-pass capacitor used to prevent degeneration. R3 is the load resistor used to develop the output signal. C3 couples the output signal to the next stage. Q1 is the amplifying device.

The phantom components representing the capacitance and inductance of the wiring are: L1, L2, C4, and C5. L1 represents the inductance of the circuit wiring. L2 represents the inductance of the output wiring. C4 represents the capacitance of the input wiring and C5 represents the capacitance of the output wiring. In view (A) the circuit is shown with an input signal that is less that 20Hz. Since the formulas for capacitive and inductive reactance are

$$XC = \frac{1}{2\pi fC}$$

$$XL = 2\pi fL$$

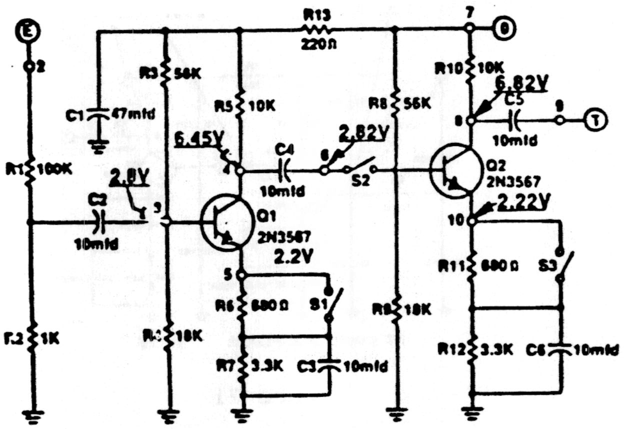
you should remember that if frequency is low capacitive reactance will be high and inductive reactance will be low. This is shown by the position of the variable resistors that represent the reactances. Notice that XL1 and XL2 are low, therefore, they do not "drop" very much of the input and output signals. XC4 and XC5 are high. These reactances tend to "block" the input and output signals and keep them from being coupled to ground. XC1 and XC2 are large at these low frequencies and greatly reduce the effectiveness of the coupling capacitors. The high reactances of the coupling capacitors will drop most of the input and output signals. The output signal below 20Hz is .707 of the maximum output amplitude and is then not considered a useable output.

Refer to view (B). Notice that all the phantom resistors are drawn with their wipper arms at the mid position. This indicates capacitive reactance has decreased and inductive reactance has increased. The most noticeable change would be to the coupling capacitors. These reactances have decreased allowing more signal to be coupled to the base of Q1 and more of the developed signal to be coupled out of the circuit. This results in a good overall gain through the audio frequency range. Now look at view (C). The input signal is a high frequency signal. Now XC is low and XL is high. Although XC1 and XC3 is now very low and will couple the input and output very effectively, XC4 and XC5 is also very low and tend to "short" or pass the input and output signals to ground. XL now being high, XL1 and XL2 now drop part of the input and output signal. The net effect is that both input and out signals are reduced. It has been shown that the frequency applied to a circuit effects the reactance of the circuit. In doing so the f1 and f2 points (half power points) will be established by the size of the components and the frequency applied to them. It is generally accepted that in an RC-Coupled amplifier the f1 point is established by the coupling capacitor and by-pass capacitor and the f2 point is set by the "shunt" or "stray wire" capacitance.

PC 33 OPERATION

During analysis of this circuit the static and dynamic values used are approximate values and may not be the same as the values that will be measured on a circuit containing the same components due to tolerances of different components.

The static voltages for the circuit were determined with S2 closed. The DC voltage at TP3 is approximately 2.8V, TP4 is 6.45V, TP5 is 2.2V, TP6 is 2.82V, TP8 is 6.82V, and TP10 is 2.22V. Refer to figure 20.



RC COUPLER AMPLIFIER PC 33

figure 20

When power is applied current will flow from ground through the base biasing networks, R3 and R4 for Q1 and R8 and R9 for Q2, to the power source. This current flow will develop a positive voltage on the base of Q1 and Q2. The base of Q1 will be approximately 2.8V and will be enough to forward bias Q1. The conduction of Q1 allows current to develop a voltage on the emitter which is approximately 2.2V and a voltage on the collector of 6.45V. The base of Q2 will be approximately 2.82V. This is enough to forward bias Q2 and cause it to conduct developing 2.22V on the emitter and 6.82V on the collector.

The other components in the circuit each perform a necessary function. R13 and C1 form a circuit known as a decoupling filter. The purpose of a decoupling filter is to prevent undesired feedback from later to earlier stages. Such a feedback might result in erratic performance or oscillation.

At a particular frequency it is possible that a signal could be riding on the supply voltage at TP7. If a signal is developed at TP7 and is felt at TP3 this would be regenerative feedback and could cause the circuit to oscillate.

C2, C4, and C5 are coupling capacitors. C3 and C6 are emitter by-pass capacitors used to prevent degeneration. R6, R7, R11, and R12 are emitter resistors used to prevent thermal runaway. These resistors are commonly called "swamping resistors". Although R1 and R2 are mounted on the card they are not actually part of the amplifiers. They are there to develop a signal that will be applied to the amplifier.

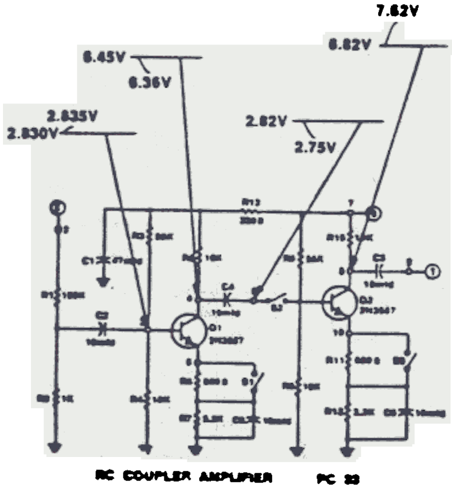


figure 21

Refer to figure 21. With an ac signal applied to this circuit at pin E, it will be felt on the left plate of C2. C2 and R4 make up the RC Coupling network for the Q1 stage. When power is applied to the circuit a positive 2.8V is felt at TP3. This means C2 is charged to 2.8V without an input trigger. As the input signal swings positive at TP2, C2 will attempt to charge to a higher potential. As C2 increases its charge, the charge current through R4 will cause the voltage drop across R4 to increase. This increase in voltage at TP3 is an increase in bias which will increase the conduction level of Q1. As the current through Q1 increases, the voltage drop across R5 increases. This results in the voltage at TP4 decreasing. In the static state TP4 measured 6.45V and TP6 measured 2.82V. C4 was then charged to 3.63V, (the difference between TP4 and TP6). As TP4 decreases, C4 will attempt to discharge. Electrons leaving the right plate of C4 will flow through R8 to VCC, adding to the current already flowing through it. This increases the voltage drop of R8 which decreases the voltage at TP6. As the voltage at TP6 decreases the bias of Q2 will decrease resulting in the conduction of Q2 decreasing. As Q2 decreases its conduction, current flow through R10 will decrease thus decreasing its voltage drop. The decrease in the voltage drop of R10 will result in an increase in voltage at TP8. If TP9 was connected to a load such as another amplifier or a piece of test equipment, C5 would now start to charge to the higher potential now felt at TP8.

Theoretically, if no load was attached to TP9 there would be no signal at TP9. However, once an oscilloscope is connected to this test point there is a path for current flow and a signal will now be developed. Refer to figure 22.

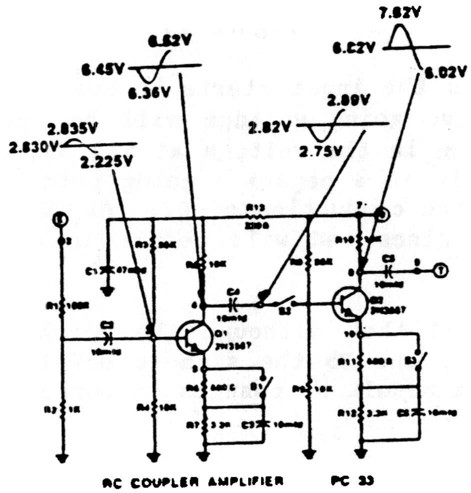


figure 22

When the input signal begins to go negative, C2 will now attempt to discharge. As the left plate of C2 goes negative, electrons will be forced off the right plate and add to the current flowing through R3 increasing the voltage drop of R3. A decrease in the voltage at TP3 which will reduce the bias of Q1 and, therefore, its conduction level. As Q1 reduces its conduction level, less current flows through R5. The voltage drop of R5 will now decrease, leaving more voltage at TP4. As the voltage at TP4 goes positive C4 will attempt to charge to this higher potential. As C4 charges to a higher potential, additional current flows through R9 increasing its voltage drop which can be measured at TP6. This increase in voltage will cause Q2 to conduct harder thus passing more current through R10. R10 now increases its voltage drop resulting in the voltage at TP8 decreasing. Again, if a load was connected to TP9, C5 would now attempt to discharge. This action will continue for the entire amount of time that the input signal is decreasing.

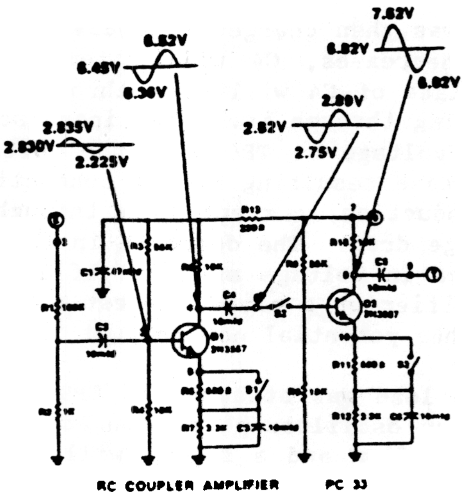


figure 23

Refer to figure 23. As the input starts to swing positive, C2 will start to recharge. A positive going voltage will be felt at TP3 and Q1 will conduct harder resulting in the voltage at TP4 decreasing. This negative going signal will result in a negative going potential being developed at TP6 which will reduce the conduction of Q2. As Q2 reduces its conduction, its collector voltage rises and will result in C5 charging to a higher potential.

It should be understood that although the signals appear to have been coupled through C2, C4, and C5 the signals developed in the circuit are actually developed as a result of changes in current due to the capacitors charging and discharging.

Normally when discussing a circuit, we speak of "signal flow" as if a signal entered the input and flowed through the circuit. It should be understood that each stage operates as an individual amplifier changing its conduction levels as the input varies.

TROUBLESHOOTING PC33

To troubleshoot PC33 you should follow the procedures outlined in the previous lesson. Since only one card is involved there will be no need to "sectionalize" (locate the proper card).

Using the oscilloscope you should first determine which stage is malfunctioning. TP9 is considered the output and TP3 will be considered the input. Either TP4 or TP6 could be the half-split point. If no signal is present at TP9 the next check will be TP3. If this signal is normal next check TP6. A good signal here indicates that the Q2 stage is malfunctioning. If no signal is present at TP6 check TP4. If TP4 is normal C4 is faulty. If there is not a signal at TP4 the Q1 stage is bad.

You have now localized the problem. Once the faulty stage is located the next step is to "isolate" to the faulty component. Using the DMM measure the DC voltages at the collector, base, and emitter and compare them to the normal voltage readings. Determine whether the bias increased or decreased and why, and whether the transistor reacted as the bias directed it to do.

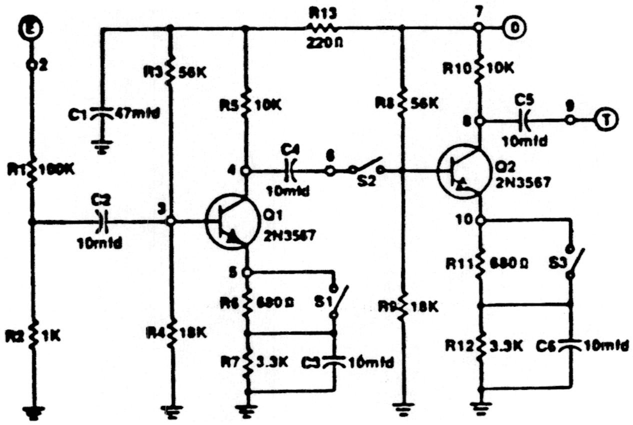


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figure 24

For example: we see that the normal voltages are TP4 6.04, TP3 2.83, TP5 2.22. Compare these to the malfunction voltages TP4 11.8V, TP3 0V, and TP5 0V. If R3 was open TP3 would decrease to 0V because there is now no path for current through R4, therefore, no voltage (0V) drop across R4. With 0V felt at the base of Q1 it should cutoff because of the no bias condition. If Q1 is cutoff, its collector voltage would read very near the applied voltage. With Q1 cutoff TP5 would read 0V because no current would flow through R6 and R7 to develop a voltage drop.

Once you have decided which component is bad you can use the ohmmeter to confirm your selection. When checking the resistance of a component it is important to look for alternate current paths if the resistance reading is not what you expected.

SUMMARY: There are three types of coupling covered during this conference; Transformer, RC-Coupling and Direct Coupling. Transformer coupling is used for impedance matching but is limited in it's ability to pass a wide band of frequencies. RC-coupling, which is the most common, is cheap and has a wide frequency response. It's main disadvantage is its ability to impedance match. Direct Coupling has no signal loss or phase inversion but is very temperature sensitive and tends to be unstable. PC33 consists of two transistors in the common emitter configuration operated class "A". Both Q1 and Q2 stages provided a signal voltage gain and phase inversion. During the PE it was noted down Q2 loaded the Q1 stage down. Bandwidth was discussed and it was shown how the upper and lower half power points were determined.